



Mind the Gap

Modeling Accelerated Code Adoption

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Background

- In May 2023, MN Governor Tim Walz signed into law **Omnibus Jobs Bill SF2035**
- The bill accelerates the adoption of building energy codes for new non-residential buildings in Minnesota

(e) Beginning in 2024, the commissioner shall act on the new model commercial energy code by adopting each new published edition of ASHRAE 90.1 or a more efficient standard. The commercial energy code in effect in 2036 and thereafter must achieve an 80 percent reduction in annual net energy consumption or greater, using the ASHRAE 90.1-2004 as a baseline. The commissioner shall adopt commercial energy codes from 2024 to 2036 that incrementally move toward achieving the 80 percent reduction in annual net energy consumption.

Context



- Xcel Energy has historically treated **energy efficiency as a resource** in MN's integrated resource plan by removing expected effects of EE from forecast sales
 - This method only works when expected efficiency gains either occur through **traditional rebate programs** or are naturally-occurring and **follow a predictable trajectory**
- In addition to the Omnibus Jobs Bill, Minnesota has developed new programs focusing on energy code support
 - Focused on both code advancement and code compliance
- In light of these changes, Xcel contracted Michaels Energy to **investigate the gap caused by accelerated code advancement not captured in previous modeling**

Methodology

Adapted from PNNL's Impact of Model Building Energy Codes Studies

Current Code – Previous Code

Potential EUI Savings

EUI Savings Realized in the Field

Incremental Savings
(Savings x New Floor Space)

Annual and Cumulative Savings

Key Assumptions

Part One

Code Adoption

- Business as Usual - PNNL classifies MN's code adoption schedule as "moderate" and assumes a 4-year lag
- Accelerated Adoption – Assumes MN adopts the latest ASHRAE 90.1 standard within one year of its publication

Energy Use Intensity

- Estimated EUI for each building type based on DOE building prototype models
- Projected a 10% reduction in energy use for each code cycle, similar to PNNL estimates
- To develop EUIs for future code editions, PNNL examined BTO's Technology Roadmap reports and goals set by the Standard 90.1 development committee



Key Assumptions

Part Two

Compliance

- Assumed a 90% compliance rate for current commercial building codes and 10% compliance with previous code
- Did not assume any change in compliance overtime.

New Building SF

- Estimated the square footage of MN commercial new construction building starts based on Dodge forecasts for 2024 and 2025
- Assumed a 4% growth rate based on forecasts from multiple sources
- To account for long lead time of construction starts, assumed 50% of construction starts would be completed in forecast year and 50% in the following year



Building Segments



- Michaels targeted five building segments:
 - Office (aggregation of small/med and large)
 - Large office buildings ($\geq 100,000$ SF) accounted for 88% of 2018 MN construction start SF (Dodge Data)
 - High-rise multifamily
 - Food service
 - Retail
 - Education
- “Other” segment is based on the weighted average of segments under study (based on SF)

Study Category	2023 Building Starts (% SF)
High Rise MF	54%
Education	6%
Office	5%
Retail	2%
Food Service	2%
Other	31%

Based on New Construction Commercial Square Footage Data from TRC MN Code Program Development Report



Adoption Scenarios

Baseline Scenario

- Adoption lag of 4 years, based on “Moderate” state adoption classification by PNNL

Accelerated Scenario

- Assumes adoption of “each new published edition of ASHRAE 90.1 or a more efficient standard” in the year of publication

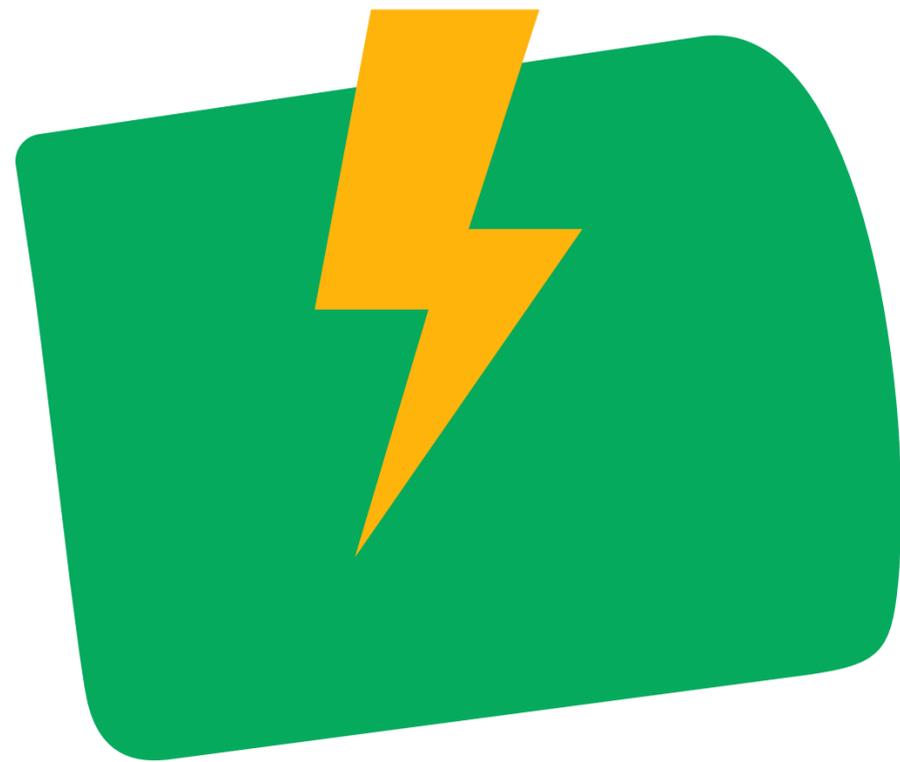
Accelerated Scenario with PV

- Accelerated Scenario plus installation of solar PV based on a prescriptive requirement of 0.5 W/SF renewable capacity based on the gross floor area of the three largest floors

Goal Scenario

- The trajectory needed to achieve an 80% reduction in annual net energy consumption, using ASHRAE 90.1-2004 as a baseline

Maximum Efficiency/Electrification Scenario

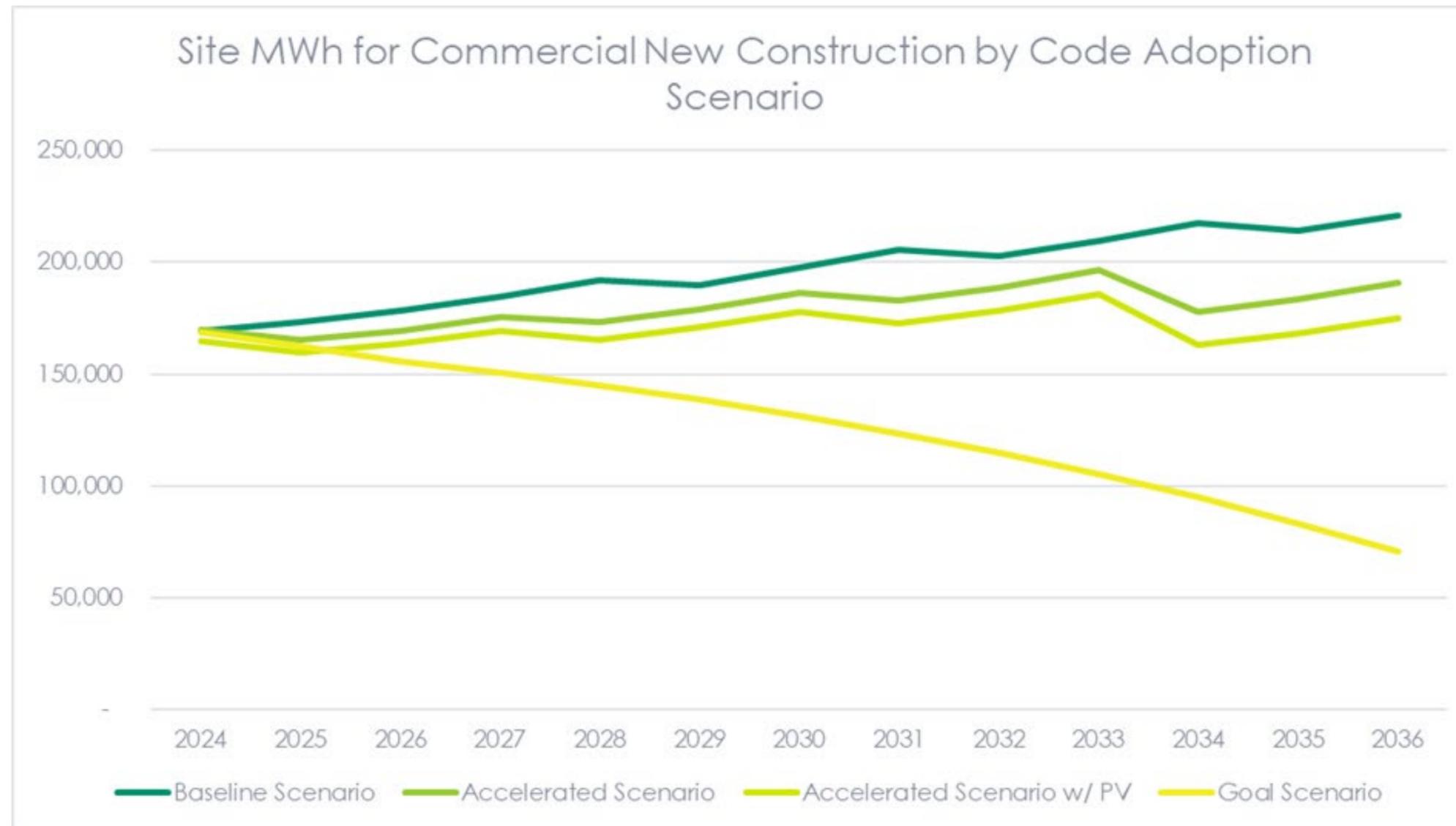


- In addition to the 4 core scenarios, Michaels also modeled a scenario assuming **all-electric buildings** and **maximum efficiency**
- Began with existing code and assumed aggressive, but realistic, technology improvements
 - Modeled building and equipment characteristics were specific to the needs of each business segment/building type

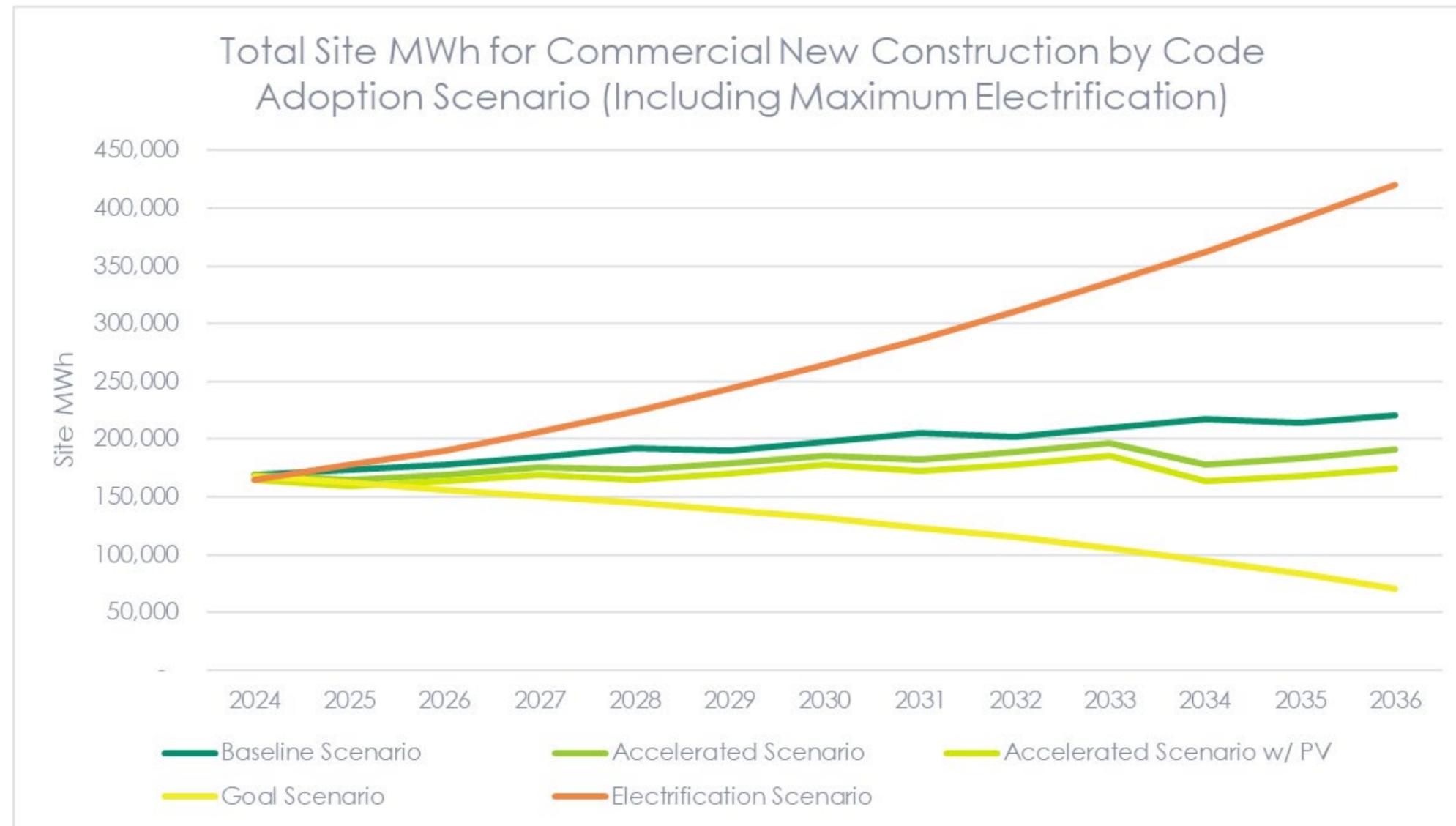


Results

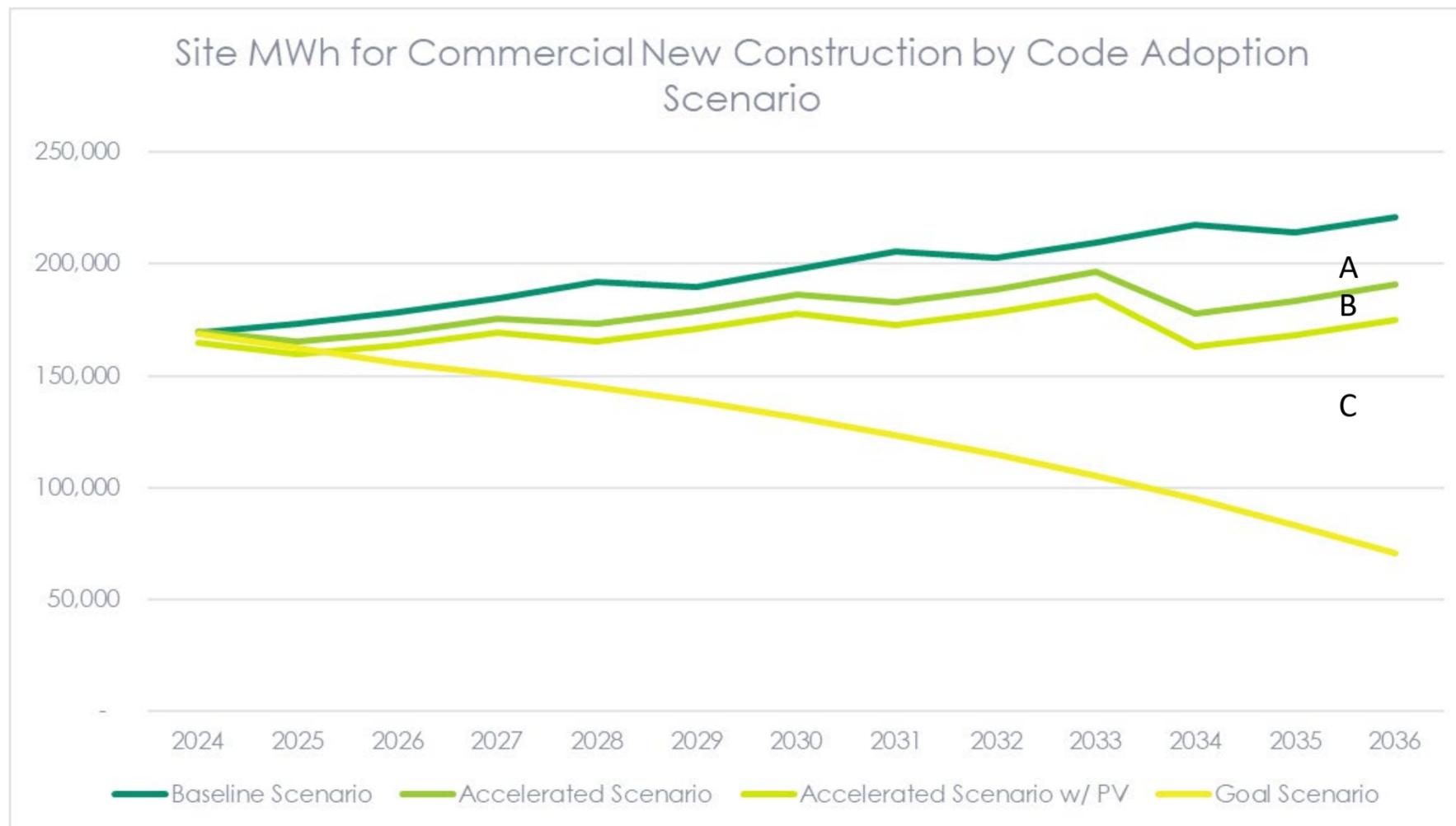
Site MWh for Commercial New Construction by Code Adoption Scenario



Site MWh for Commercial New Construction by Code Adoption Scenario



Energy Savings (2024-2036)



- Area A
 - Baseline – Accelerated
216.4 GWh
- Area B
 - Accelerated –
Accelerated w/ PV
123.9 GWh
- Area C
 - Accelerated w/ PV –
Goal **570.0 GWh**
- Areas A+B+C
 - Baseline – Goal
910.4 GWh

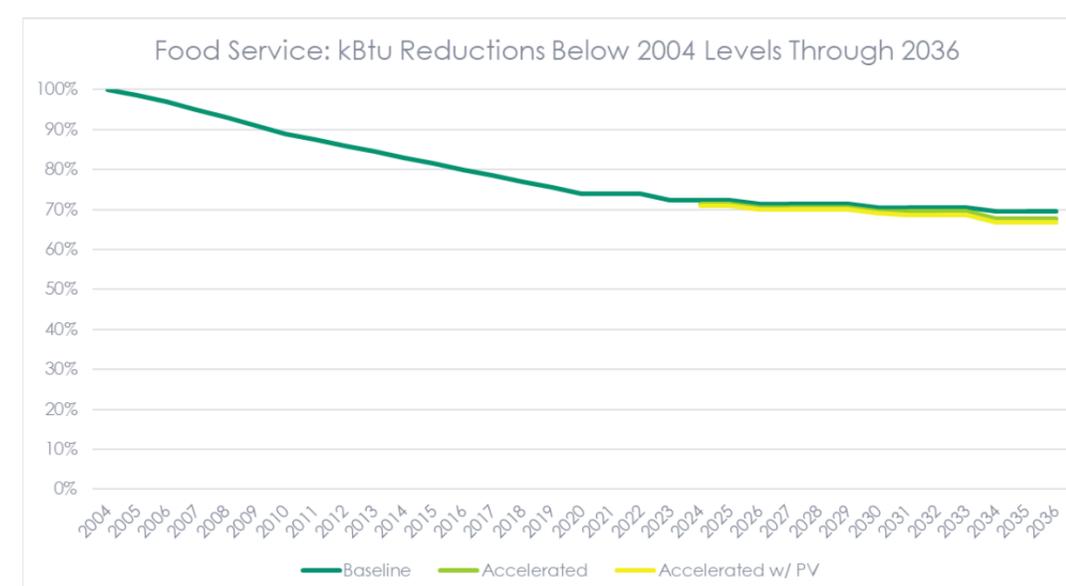
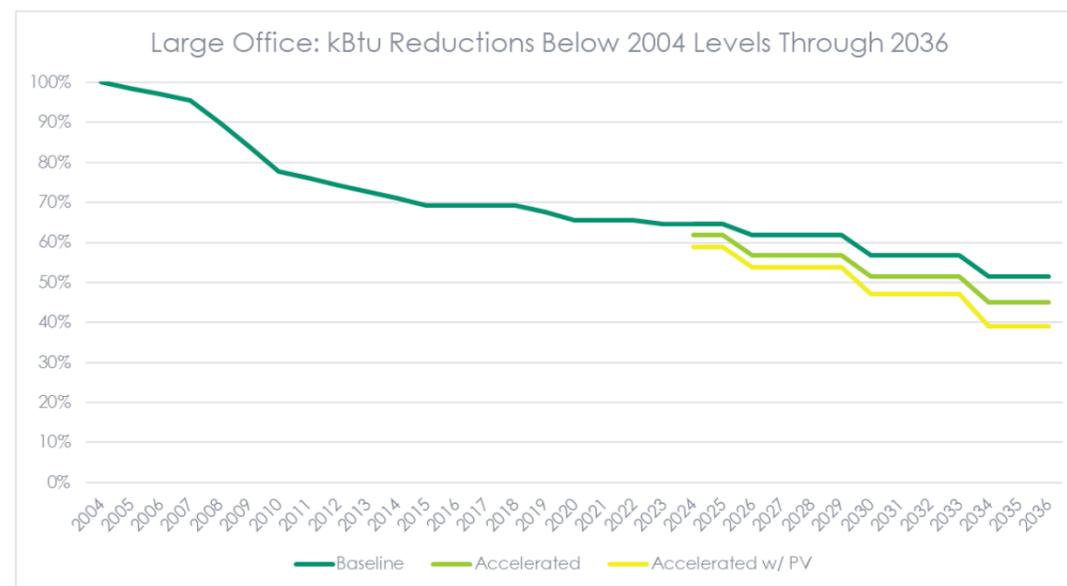
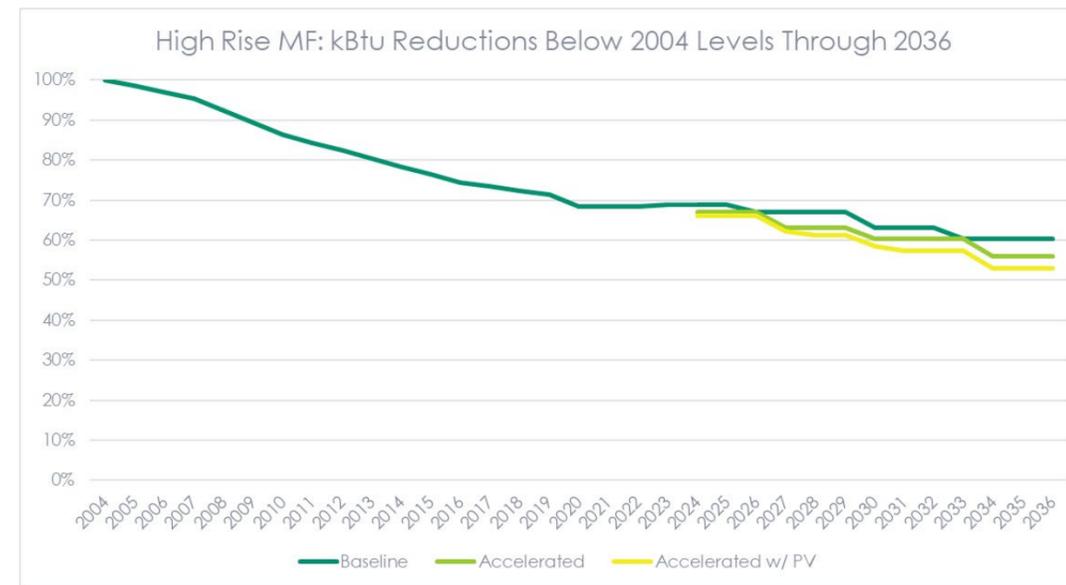
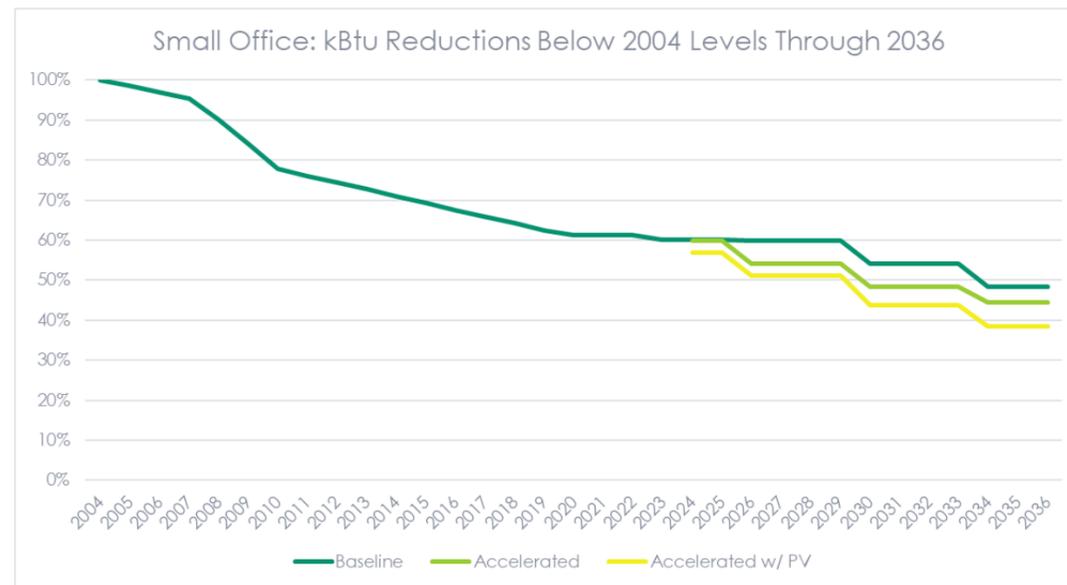


Energy Usage 2004 v. 2036

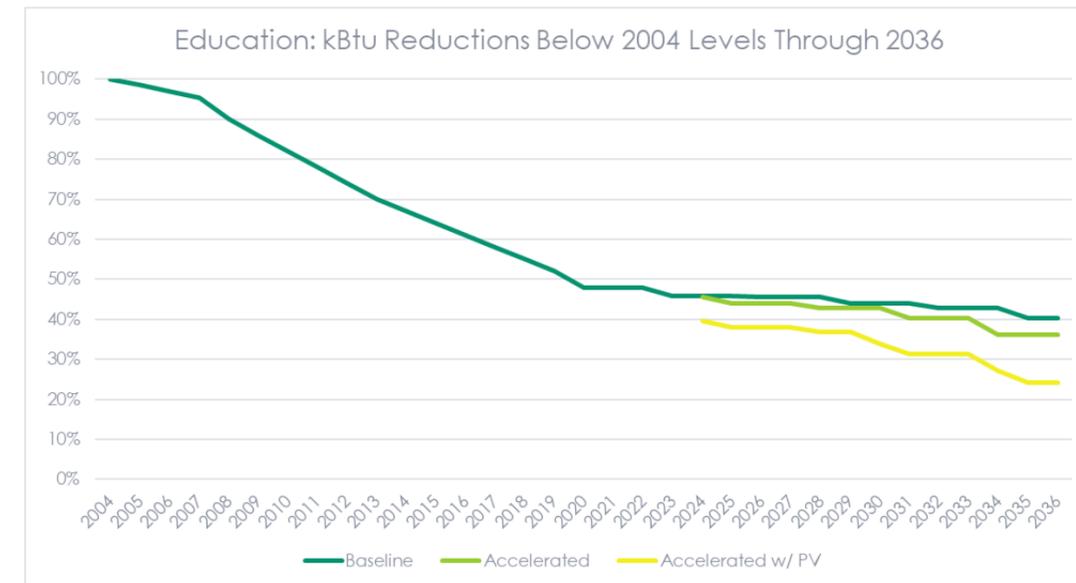
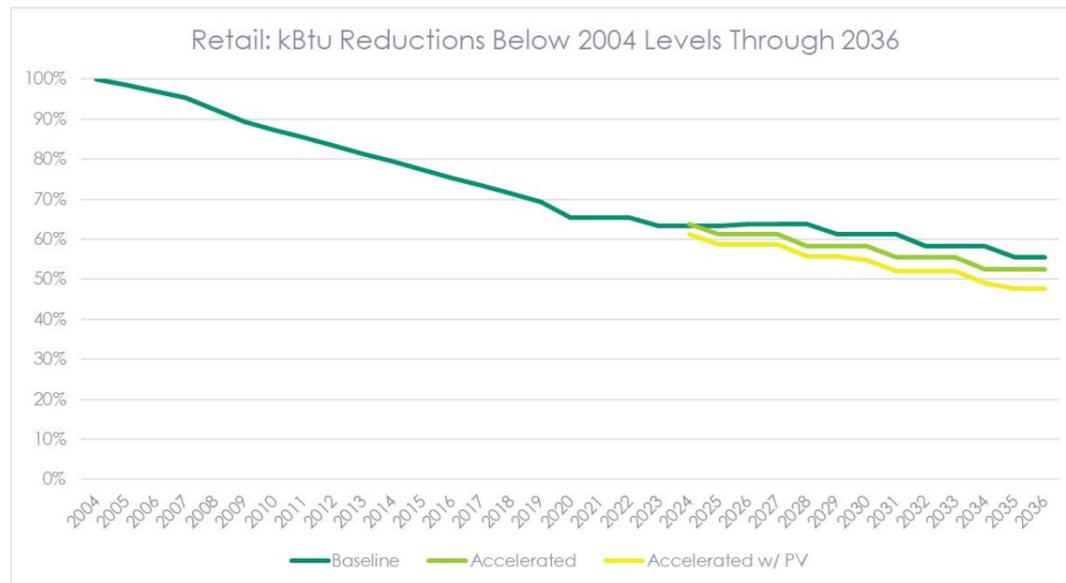
Building Type	Electric - HVAC (kWh)	Electric - Lighting (kWh)	Natural Gas - HVAC (Mbtu)	Total Site Energy (kBtu)	Total Site Energy w/ PV (kBtu)
Small Office	50%	21%	52%	45%	37%
Large Office	65%	26%	37%	45%	43%
High Rise MF	55%	58%	56%	56%	54%
Food Service	57%	19%	77%	68%	67%
Retail	43%	25%	73%	52%	48%
Education	43%	20%	37%	36%	24%



Results by Segment



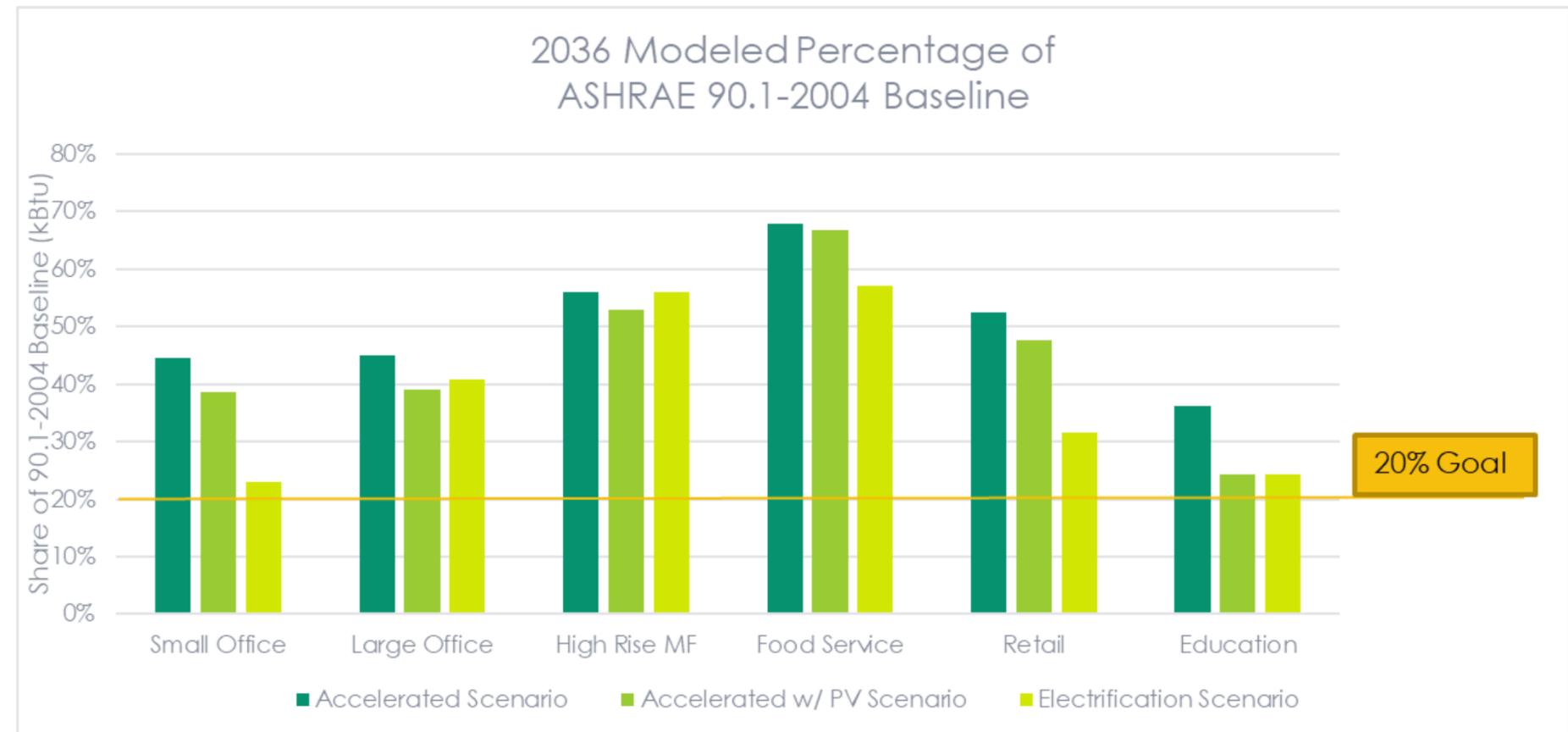
Results by Segment, Continued



Scenario Comparison



- The accelerated code scenario only gets to about 40-50% of the 2004 baseline
- To achieve the goal reduction, more aggressive renewable and efficiency assumptions will be necessary
- Electrification and aggressive efficiency improvements can come close to the goal energy consumption for some building types, but not all



Efficiency Opportunities

Mechanical Trends

- Variable Refrigerant Flow/Volume (VRF/VRV) Systems
- Ground Source Heat Pumps

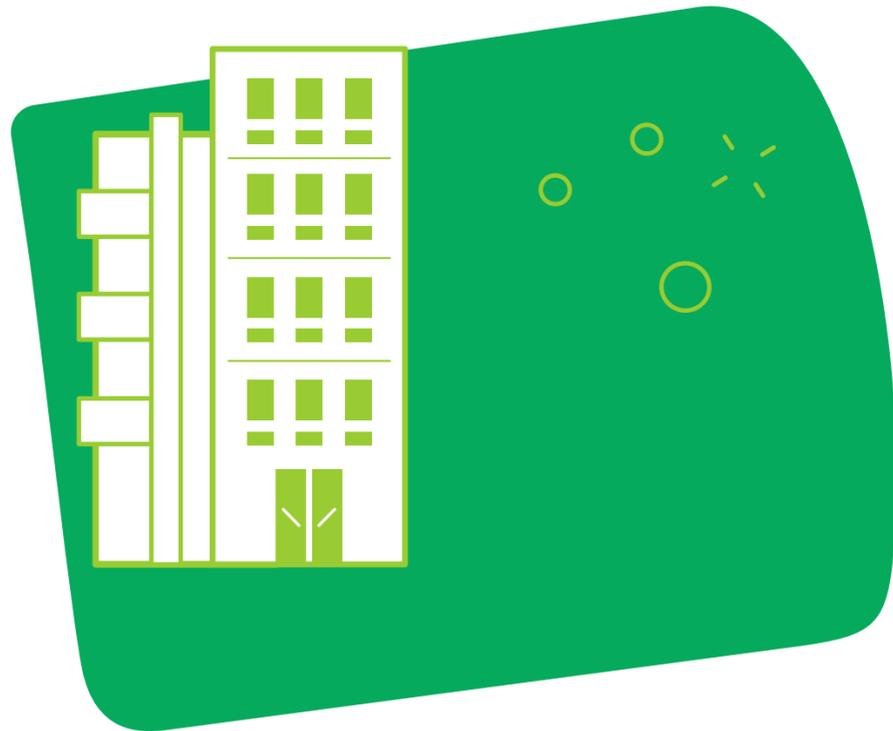
Variable Air Volume (VAV) Trends

- Supply air static pressure reset
- Supply air temperature reset
- Ventilation optimization
- VAV terminal unit dual max control

Technologies

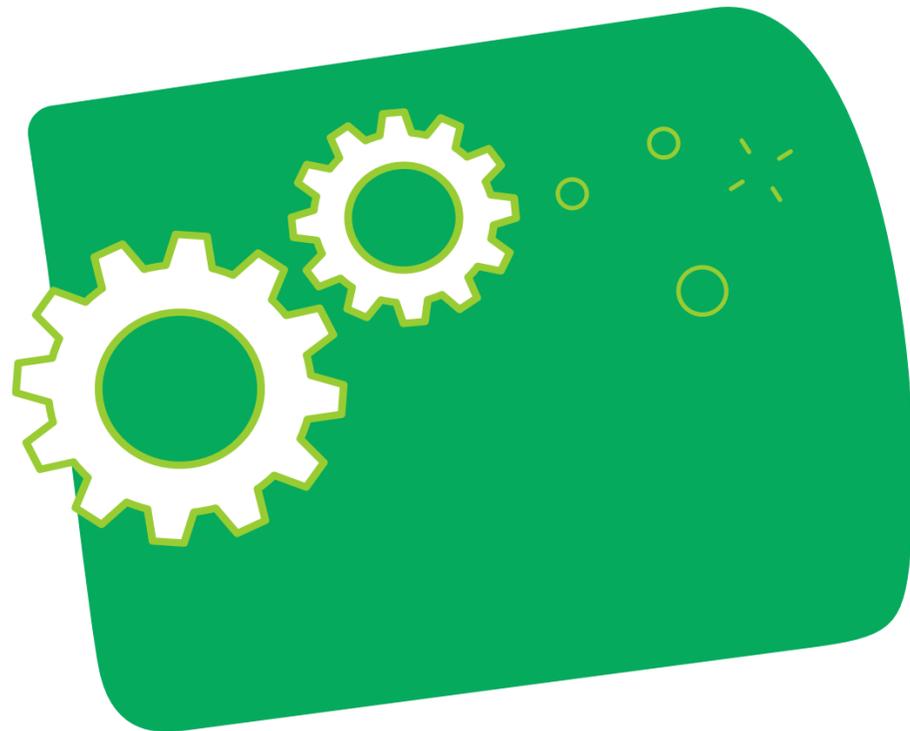
- Dual-fuel HP packaged RTUs
- Low-ambient heating packaged HPs
- Inverter technology compressors
- Heat recovery VRF/VRV systems
- Airside energy recovery

Key Takeaways: Variability



- The ability of each building segment to achieve prescribed EUI reduction may vary widely
- Some segments, especially MF housing, may face significant challenges without transformational new efficiency technologies
- It may be necessary to take a “portfolio -level” view to determine if state policy goal to reduce EUI through building codes is on -track
 - Some segments may achieve greater EUI reductions while others achieve less
- Portfolio -level approach could make achievement of policy goal more susceptible to market -level shifts outside of control of administrators (e.g., MF real estate market)

Key Takeaway: Complexity



- Modeling efficiency, electrification, and distributed generation and higher performing energy codes is complex!
- This analysis used simplifying assumptions to help mitigate this complexity (e.g., limited number of building types and end uses)
- Simplifying assumptions may need to be revisited before replicating this analysis in other regions
 - E.g., impact of space heating vs. space cooling

Key Takeaway: System Planning



- Near quadrupling of electricity demand between goal scenario and electrification scenario
- Pursuit of state policy goal to improve building performance should not compromise decarbonization trajectory of the electric grid
- Requires linking utility programs, code advancement, and utility planning decisions

Thank you!

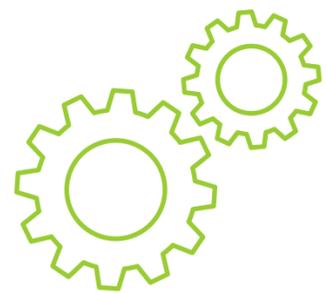


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Appendix



2030/2036 Model Inputs for Max Efficiency



- Max window glazing area: **25%** in 2030 / **20%** in 2036 (reference 30% in 90.1-2016)
- Interior lighting LPD: **75%** of 2019 (2030) / **50%** of 2019(2036)
 - Aggressive, but anticipated reduction includes daylighting control, full transition to LED, lighting occupancy/vacancy/lighting level controls.
- Exterior lighting LPD: **75%** of 2019 (2030) / **50%** of 2019(2036)
 - Aggressive, but anticipated reduction includes significant transition to LED, better lighting level controls, gratuitous site and façade lighting limitations.
- Air infiltration / exfiltration: **90%** of 2019 (2030) / **80%** of 2019 (2036)
 - Assumed stricter requirements on HVAC building pressure control, greater focus on building orientation and wind pressure mitigation, and a moderate increase in building air barrier performance.
- Air cooled packaged systems:
 - **4.2 COP** (2030, 19.4 IEER). min 2 stage all coils – digital or inverter over 5 HP
 - **4.6 COP** (2036, 24.5 IEER). min 2 stage all coils – digital or inverter over 2 HP
- Water cooled chiller:
 - **10.00-COP** (2030, 0.35 IPLV kW/ton)
 - **11.72-COP** (2036, 0.30 IPLV kW/ton)
- Fan overall (W/cfm):
 - Pressure Rise: SZ/RTU ducted **2.5"** w.c.; central VAV **4"** w.c.; zonal system/FCU **1"** w.c.
 - Total Fan Efficiency: **70%** (same 2030 / 2036)
- Gas heating:
 - Hydronic boilers: **95%** efficiency
 - RTU furnace sections: **85%** efficiency (same 2030 / 2036)
 - **2036 dual fuel RTUs** – heat pump to 20F, then gas heat for lower ambient
- Plug loads: (May be needed to achieve 20%?)
 - Multiplier: **85%** of 2019 (2030) / **75%** of 2019 (2036)
- Refrigeration – **85%** of 2019 (2030) / **75%** of 2019 (2036)
- PV: **0.75** W/sf (2030) / **1.0** W/sf (2036) (gross floor area of 3 largest floors)
- Pumping Energy: (no changes ?)
- Service hot water trends:
 - **90%** efficiency condensing boilers (2030 / 2036)
 - Require heat recovery chillers water cooled for schools, hospitals, multi-family, dormitories, etc.
 - Require heat pump water heating for smaller commercial systems.

Electrication Scenario Assumptions



System Tag	Description	Found in Models	Representative DX Cooling Size (MBH)	Representative HP Heating Size (MBH)	90.1-2022 Code Minimum (for reference)				Current High Performance			Basis of Design Model
					Cool EER	Cool IEER	Heat COP @ 47°	Heat COP @ 17°	Cool EER	Cool IEER	Heat COP @ 47°	
Packaged HP RTU	Rooftop CV packaged heat pump, 2 stages DX cooling, low-ambinet heating option, emergency electric heat	Large Office Food Service Retail Small Education	120,000	118,000	10.8	13.9	3.4	2.25	12.3	13.6	3.50	Carrier "WeatherMaster" 50HCQD12
									10.5	13.5	3.20	York "Sun Pro" XP150
									12.4	19.3	3.42	Daikin Applied "Rebel" DPS010
									11.5	15.5	3.63	Trane "Precedent" WHC120
Packaged HP SZVAV	Rooftop SZVAV packaged heat pump, 2 stages DX cooling, low-ambinet heating option, emergency electric heat, 30% minimum fan	Food Service Retail Small Education	240,000	224,000	9.3	12.3	3.2	2.05	10.6	12.0	3.20	Carrier "WeatherMaker" 50TCQD24
									11.3	20.4	3.40	Daikin Applied "Rebel" DPS020
									11.3	20.4	3.40	Trane "Horizon" OAKE240 (similar to Rebel)
									11.2	17.7	3.60	Trane "Precedent" WHJ240
Packaged HP DOAS	Rooftop CV packaged heat pump 100% outside air DOAS, 2 stages DX cooling, low-ambinet heating option, emergency electric heat	Small Office Large Office High Rise MF Small Education	240,000	224,000	9.8	13.0	3.2	2.05	11.3	20.4	3.40	Trane "Horizon" OAKE240 (similar to Rebel)
									11.3	20.4	3.40	Daikin Applied "Rebel" DPS020
									11.2	17.7	3.60	Trane "Precedent" WHJ240
Heat Recovery VRF	Multi-zone heat recovery variable refrigerant flow (VRF) system, simultaneous heating/cooling, refrigerant-based heat recovery, low-ambinet heating	Small Office Large Office High Rise MF Small Education	192,000	215,000	10.3	14.9	3.2	2.05	12.6	20.4	3.67	Daikin "VRV IV X" REYQ192T
									11.0	23.0	3.30	LG "Multi V5" ARUM192
									12.8	18.8	3.71	Mitsubishi "Y Series" PUHY-HP192YSNU-A



Electricity HVAC Tech Improvement



	2024 Avg Cool COP	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036
		2.86%	2.86%	2.86%	2.86%	2.86%	2.86%	0.95%	0.95%	0.95%	0.95%	0.95%	0.95%
Packaged HP RTU	4.14	4.26	4.38	4.51	4.64	4.77	4.90	4.95	5.00	5.05	5.09	5.14	5.19
Packaged HP SZVAV	4.32	4.44	4.57	4.70	4.84	4.97	5.12	5.16	5.21	5.26	5.31	5.36	5.42
Packaged HP DOAS	4.50	4.63	4.76	4.90	5.04	5.18	5.33	5.38	5.43	5.48	5.53	5.59	5.64
Heat Recovery VRF (cooling mode)	6.08	6.25	6.43	6.62	6.81	7.00	7.20	7.27	7.34	7.41	7.48	7.55	7.62

	2024 Avg Heat COP	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036
		2.86%	2.86%	2.86%	2.86%	2.86%	2.86%	0.95%	0.95%	0.95%	0.95%	0.95%	0.95%
Packaged HP RTU	3.44	3.54	3.64	3.74	3.85	3.96	4.07	4.11	4.15	4.19	4.23	4.27	4.31
Packaged HP SZVAV	3.40	3.50	3.60	3.70	3.81	3.91	4.03	4.06	4.10	4.14	4.18	4.22	4.26
Packaged HP DOAS	3.47	3.57	3.67	3.77	3.88	3.99	4.11	4.14	4.18	4.22	4.26	4.30	4.35
Heat Recovery VRF (heating mode)	3.56	3.66	3.77	3.87	3.98	4.10	4.22	4.26	4.30	4.34	4.38	4.42	4.46

- Baseline and technology improvement assumptions are similar to those used in other modeling for Xcel Energy



Mechanical Upgrades, Electrification Scenario



Building Type	Baseline	2036 Model (Alt-1)	2036 Model (Alt-2)
Small Office	<ul style="list-style-type: none"> - AC Packaged Rooftop VAV - 25% minimum supply airflow - 2spd DX Clg Coil (4.60 COP) - Indirect gas heat (95% eff) - Shut-off VAV w/ HW reheat - Gas-fired service HW 	<ul style="list-style-type: none"> - HP Packaged Rooftop VAV with low ambient heating - 25% minimum supply airflow - 2spd DX Clg Coil (4.60 COP) - Heat pump heating (___COP) - Electric shut-off VAV w/ reheat - Electric tank service HW 	<ul style="list-style-type: none"> - VRF multi-zone heat recovery - Low-ambient heating VRF - Packaged HP DOAS Vent - Electric tank service HW
Large Office	<ul style="list-style-type: none"> - Water cooled chillers (11.7 COP) - Condensing boilers (90% Eff) - VAV airside. CHW / HW coils - Enthalpy exhaust heat recovery - 25% minimum supply airflow - Shut-off VAV w/ HW reheat - "data center" heat pump loop - Gas-fired service HW 	<ul style="list-style-type: none"> - Water cooled heat recovery chillers transfer to low-temp heating HW loop. - HW low-temp HP in tandem with heat recovery chillers - VAV w/ exhaust heat recovery - 25% minimum supply airflow - Shut-off VAV w/ HW reheat - HW low-temp HP heating loop - "data center" heat pump loop - Electric tank service HW 	<ul style="list-style-type: none"> - VRF multi-zone heat recovery - Low-ambient heating VRF - Packaged HP DOAS Vent - Electric tank service HW - "data center" switched to DX with electric heat
High Rise MF	<ul style="list-style-type: none"> - Conventional packaged unitary heat pumps. - Ventilation at each unit - Evaporative fluid cooler - Condensing boilers (90% Eff) - Gas-fired service HW 	<ul style="list-style-type: none"> - Conventional packaged unitary heat pumps. - Central packaged HP DOAS ventilation ducted to zones - Evaporative fluid cooler - Electric heating boilers for the condenser loop - Electric tank service HW 	<ul style="list-style-type: none"> - VRF multi-zone heat recovery - Low-ambient heating VRF - Packaged HP DOAS Vent - HP service HW. Possible VRF rejection to service HW loop.

Shaded cells indicates selected 2036 scenario



Mechanical Upgrades, Electrification Scenario, Cont'd



Building Type	Baseline	2036 Model (Alt-1)	2036 Model (Alt-2)
Food Service	<ul style="list-style-type: none"> - AC Packaged Unitary Rooftop - Constant speed fan, always on during occupancy - 2spd DX Clg Coil (4.60 COP) - Indirect gas heat (80% eff) - Gas-fired service HW - Mix of gas / elect kitchen equip 	<ul style="list-style-type: none"> - HP Packaged Rooftop SZVAV with low ambient heating - 30% minimum supply airflow - 2spd DX Clg Coil (4.60 COP) - Heat pump heating (5.0 COP) - Electric tank service HW - High eff electric only kitchen 	VRF is not a great fit for food service. Generally try to avoid servicing equipment from within the space, much better to have roof service.
Retail	<ul style="list-style-type: none"> - AC Packaged Unitary Rooftop - Constant speed fan, always on during occupancy - 2spd DX Clg Coil (4.60 COP) - Indirect gas heat (81% eff) - Gas-fired service HW 	<ul style="list-style-type: none"> - HP Packaged Rooftop SZVAV with low ambient heating - 30% minimum supply airflow - 2spd DX Clg Coil (4.60 COP) - Heat pump heating (5.0 COP) - Electric tank service HW 	VRF may be a good selection for some standalone retail spaces. However, it's best to anticipate this following a similar rooftop unit approach as is typical today.
Education	<ul style="list-style-type: none"> - AC packaged DX with heating hot water coils. (4.5 COP) - Condensing boilers (95% Eff) - VAV multizone. DX / HW coils - Enthalpy exhaust heat recovery - 25% minimum VAV supply airflow - Shut-off VAV w/ HW reheat - Gas-fired service HW 	<ul style="list-style-type: none"> - VRF multi-zone heat recovery - Low-ambient heating VRF - Packaged HP DOAS Vent - Electric tank service HW 	<ul style="list-style-type: none"> - Conventional or ground source packaged unitary heat pumps for each classroom. - Central packaged HP DOAS ventilation ducted to zones - Evaporative fluid cooler - Low-ambient HP heating in lieu of boilers for condenser loop - HP service HW

Shaded cells indicates selected 2036 scenario

